

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

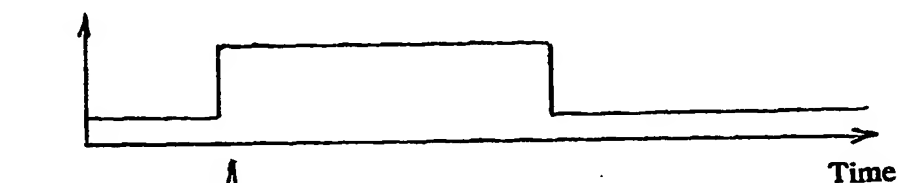
(51) International Patent Classification ⁶ : G01N 27/416, 33/14		A1	(11) International Publication Number: WO 99/13325
			(43) International Publication Date: 18 March 1999 (18.03.99)
(21) International Application Number: PCT/SE98/01583		(81) Designated States: AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GE, GH, GM, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).	
(22) International Filing Date: 7 September 1998 (07.09.98)			
(30) Priority Data: 9703215-5 7 September 1997 (07.09.97) SE			
(71) Applicant (for all designated States except US): NORDIC SENSOR TECHNOLOGIES AB [SE/SE]; Teknikringen 6, S-583 30 Linköping (SE).			
(72) Inventors; and (75) Inventors/Applicants (for US only): WINQUIST, Fredrik [SE/SE]; Heidenstams gata 34, S-584 37 Linköping (SE). WIDE, Peter [SE/SE]; Järsta 3, S-681 93 Kristinehamn (SE).			
(74) Agent: BERGLUND, Erik; Berglunds Patentbyrå AB, S-590 55 Sturefors (SE).			
		Published <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>	

(54) Title: **ELECTRONIC TONGUE**

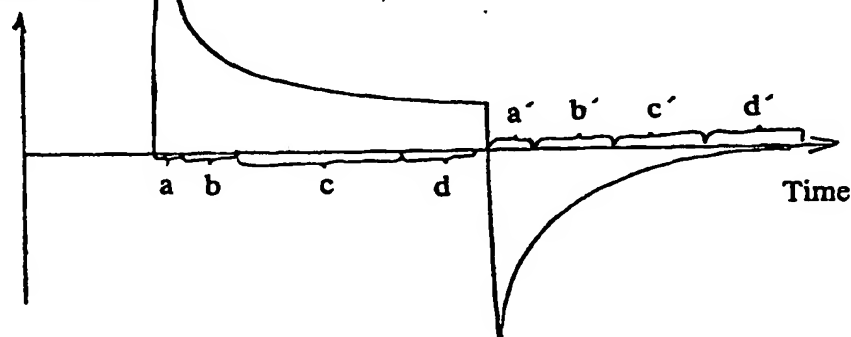
(57) Abstract

Electronic tasting carried out by feeding short electrical pulses to electrodes and a registration of current and/or voltage transients for these pulses (at distinct times). For each test sequence a number of pulses with different voltages are used. The obtained signals are then recognized or compared by a pattern recognition program in a computer for instance to see if a liquid substance such as beer or milk lies within set quality limits.

Voltage (V)



Current (A)



Curve A

Curve B

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

ELECTRONIC TONGUE

There is a growing interest in recent years for the concept of electronic noses. An electronic nose consists of an array of gas sensors with different selectivity patterns, a signal collecting unit and pattern recognition software applied to a computer. The principle is based on the fact that a large number of different compounds contributes to define a measured odor, the chemical sensor array of the electronic nose then provides a pattern output that represents a synthesis of all the components. The pattern output is given by the selectivities of the various sensors. The very essence of the electronic nose is that the combination of several specificity classes has a very large information content.

Electronic noses have already been established for qualitative analysis in various fields of the analytical chemistry, and there are already commercial instruments on the market. Due to the similarities with the human olfaction, these systems have been cited as "electronic noses". Recently, similar concepts, but for analysis in liquids, have been described. These systems are in similar ways related to the tasting sense, thus, for these concepts the terms "electronic tongue" or "taste sensor" have been coined. An electronic tongue was thus described based on a number of chalcogenid glass electrodes, combined with a pattern recognition routine for measurement of metal ions in river water (Ref 1). A more complex sensor composition consisting of glass electrodes and PVC membranes for tasting of beverages has also been described (Ref 3).

Similar concepts, denoted "taste sensors", have also been described. Thus, a LAPS (light addressable potentiometric sensor) with artificial lipid membranes as ion selective material has been described (Ref 4), as well as taste systems, based on a fibreoptical sensor array using potential sensitive dyes (Ref 5) or on a surface photovoltage technique applied to Langmuir-Blodgett films (Ref 6).

A taste sensor based on lipid/polymer membranes on a multichannel electrode has also been developed (Ref 2). This concept has been commercialized as Taste Sensing System SA401, by Anritsu Corp., Japan.

A common feature for these electronic tongues or taste sensors described, that the sensing

principle is based solely on potentiometry, the charging of a membrane being measured. This will limit the area of detectable compounds to ions or other charged species.

Thus, these known taste sensors are not sufficiently discriminating to allow for instance quality monitoring in e.g. food processes. The variation in the response to different parameters is not sufficient and despite the use of pattern recognition methods as known from the electronic nose technique the resulting patterns are not separable with sufficient precision.

Furthermore, potentiometric measurements per se are sensitive to electronic noise, putting high demands to the electronics and measurement set-up.

In view of the above mentioned problems encountered with known taste sensors or electronic tongues the object of the invention is to improve the pattern response to variations in tested substances. This object is achieved by a generation of transients by applying electrical pulses to electrodes in contact with the substance to be investigated. For instance voltage pulses may be applied and the current be monitored. Transients will appear at the front and at the rear of the measured current pulse. The transients or some part thereof is then registered and used for comparison purposes, either with measurements at preceding pulses to control continuity in for instance a production process or for comparison what we could call a library of previously registered values for substance detection purposes. For the purpose of simplicity we have in the following mainly discussed the initial transient, however the pulse end transient can be used in a similar manner and at times it may perhaps be of advantage to use measured values from both transients.

Normally in voltametry for instance, the very first moments when electricity is applied to the electrode is not considered at all and one normally waits for the more steady and thus more easily predictable conditions that follow. For the invention which may be employed to give an electronic tongue, it has, however, been found that the initial signal transient response obtained when electricity is applied will vary significantly when the tested substances vary and thus the pattern will also vary with different voltages, pulse wave forms and frequencies.

Contrary to known measuring the initial transients are recorded instead of the later stabilized conditions. The great variation obtained is however of great advantage in the invention (for instance an electronic) tongue were the important thing is to achieve as different patterns as possible for small changes in test substance. Whether the changes in signal response are predictable in a calculable sense of the word or not are however without interest provided that a given change result in the same recognition pattern change every time, which it does. The normal disadvantage can thus be considered as an advantage at the invention.

The use of the transients for recognition (analysis) or monitoring can be done in many different ways. The entire transient curve can be registered and processed or the values at specific times from pulse onset may be used. These values can then be treated by multivariate methods to gain the desired information or control parameters. If these are few only a few significant measured transient values may suffice either consisting of perhaps as little as one value taken after pulse onset but before the peak value, of the peak value only or of a value taken very shortly after the peak, within for instance 90% or preferably 95% of the peak value. Of course also combinations of these can be considered.

In particular when the transient measurements are used together with multivariate methods the resolution or precision may be enhanced by for instance varying the pulse amplitude, for instance the voltage at voltammetry. Due to the difference in electric field strength the present substances will react, in particular move, with differing agility depending on size, binding to other substances etc.

In order to also increase the base for multivariate evaluation other parameters the pulse amplitude may be varied as for instance electrode material, pulse frequency, superimposed DC-voltage, catalytic influence and influence from other electrodes. Also different or varying pulse wave forms and/or frequencies, between which a base potential can be applied or superimposed can be considered.

The response signal, for instance the current transient at voltammetry may be measured during the forward step of a square pulse, after return to the initial condition, or both, and

if time is in good supply one may also register the equilibrium value between the transients. However one great advantage of the invention is the great speed with which a cascade of identical or differing measurements can be carried out due to the extremely short lived transients, for instance monitoring cycle time can be much shorter than control induced process variations. For the measuring so called "Phase Lock" methods can be used.

The pulse generated may have various origins, the principle may be based on measurements on current, voltage, effect, energy or conductivity, due to onset of pulses of voltage, current or combinations thereof.

The instantaneous faradic current at the electrode is related to surface concentrations and charge transfer rate constants, and exponentially to the difference of the electrode potential from the start value to the final potential. Various parts of the curve thus reflects amount and type of either charged or electroactive species in a complicated and superimposed way.

The current - time curve shape (A) due to the onset of a voltage pulse is schematically shown in figure 1.

At least four regions can be distinguished:

- a/ Incoming charged and/or redox active species starts to build up a Helmholtz layer. This region is dominated by type and amount of charged species.
- b/ Mixed region of incoming charged (dominating part) and/or redox active species
- c/ As in b above, but the reaction of redox active species is the dominating part of the current.
- d/ Equilibrium is achieved, and the current is solely based on reduction/oxidation of redoxactive species.

Curve B (transient at the end of the pulse) is essentially reversed from that of A. A different shape is, however, obtained due to the different compounds near the electrode surface.

If the voltage pulses are superimposed by a variable signal, for example on a voltage ramp, the corresponding current-time curve will be as shown in figure 2. Similar interpretations as in the previous case can be made.

If in a further development of the invention only or mainly the first part of the transient is measured and used the advantage is gained that a very rapid testing or tasting can be carried out since the first part of the transient is of a very short duration. With the first part is here meant the first rising slope up to the peak. Possibly measurements a short time after this can also be used. However the use of the rising slope of the transient has the advantage of allowing a very rapid pulse frequency resulting in rapid control of for instance food processing. Transients and variations in the control sequences can thus be avoided by using the "taste transients". The achieving of these exceptional results are actually adverse to normal chemical testing since no stable conditions are achieved and instead the chaotic more or less unanalyzable relations are used for the analysis.

Since the pulses may be short the influence of the measuring on the tested substance may become negligible, also the shape and size of the electrodes may be chosen more freely. For instance the electrodes may have a larger size than normally increasing the signal response and an integration over a larger area or volume of the measured substance, diminishing the risk of undesired substance variation influence. Also the short pulses allow rapid testing or monitoring as well as the collection of responses from a great number of pulses with different voltages.

In one configuration of the invention two types of pulse voltammetry may be used, based on large amplitude pulse voltammetry and small amplitude pulse voltammetry, in the following abbreviated as LAPV and SAPV, respectively.

In LAPV, the electrode is held at a base potential, at which negligible electrode reactions occur. After a fixed waiting period, the potential is stepped to a final potential. A current will then flow to the electrode, initially sharp when a Helmholtz double layer of charged species is formed and electroactive compounds next to the electrode surface are oxidized or reduced. The current will then decay exponentially as the double layer capacitance is

charged and electroactive compounds are consumed, until the diffusion limited faradic current remains. The size and shape of the transient response reflects amount and diffusion coefficients of both electroactive and charged compounds in the solution. When the electrode potential is stepped back to its start value, similar but opposite reactions occur.

In the SAPV, a slow continuous DC scan is applied to the electrode on to which small amplitude voltage pulses are superimposed. This will cause a change in the concentration profile of the electroactive species at the surface. Since only small changes in the electrode potential are considered, this will result in small perturbations in the surface concentration from its original value prior to the application of the small amplitude excitation.

When using pulsed voltammetry, information can also be obtained from AC current versus frequency curves at various potentials. The potential may vary around zero (fig 4) or be superimposed on an other arbitrary statical or dynamical potential curve (fig 6).

In continuous voltammetry, the current depends of the diffusion rate of electroactive species to the working electrode. If the stirring rate in the measurement cell is changed, also the electrode current is changed. One way to overcome this is to use microelectrodes, due to favourable diffusion profiles, an other way is to use pulse voltammetry, conductometry, effect or energy measurements.

Pulse voltammetry also enables the use of macroelectrodes that can be cleaned by rather harsh methods, which often is necessary to get clean electrode surfaces. Microelectrode are much more fragile.

The invention also deals with the aspect of influencing the measured solution at one position and to make measurement at an other position, so close that measurement will be affected. This means that compounds generated at one electrode are detected (together with other compounds in the solution) by the other electrode. Since both electrodes may be operated at different potentials and pulse conditions, a very large but also very complicated information concerning the measured solution may be obtained increasing the possible variations in the transients and thus provide a big base for the pattern recognition. In case

of streaming or flowing liquids being tested influencing electrodes or materials as for instance catalytic materials can be placed upstream of some electrodes to change the composition before it is tested by other electrodes.

Further developments of the invention are apparent from the subclaims and the following description of experimental tests of the invented method. The description refer to the appended drawings showing:

- Figure 1 A schematic current-time transient due to the on/off set on a voltage pulse;
- Figure 2 A schematic current-time transient due to the on/off set on a voltage pulse, superimposed on a ramped voltage onset;
- Figure 3 Schematics of an experimental set-up;
- Figure 4 A typical recording from LAPV, also showing the position of measurement points. Pulse time and time between pulses are also indicated;
- Figure 5 A typical recording from SAPV, also showing the position of measurement points. Pulse time and time between pulses are also indicated.
- Figure 6 Score plot for the experimental series. The samples were investigated after each other as shown in Table 1.

The basic principle behind the electronic tongue is to combine unspecific and overlapping signal transients with pattern recognition routines. Within this invention, various pulsed voltammetric techniques can be applied to generate information when combined with a multivariate method, such as principal component analysis, partial least square fits, artificial neural nets, fuzzy logic, genetic algorithms or similar statistical or "artificial intelligent" methods. In the invention, also various curve fitting methods may be used to characterize the pulse responses obtained.

The invented method can normally be divided into four steps:

- Use of pulse voltammetry (or other electrical measurement methods) to obtain information (transient curves) ;
- Use of different electrode materials or modified electrodes or pulse voltage etc to obtain different chemical reactions varying the transients;
- Use of curve fitting methods to extract or sample information from the obtained set of transients;
- Use of various multivariate signal processing methods to interpret this thereby gained information.

Prototype variations of the invention

A prototype of an electronic tongue has been designed, based on the combination of pulse voltammetry using two types of working electrodes and principal component analysis (PCA). This electronic tongue was able to classify various samples, such as fruit juices, still drinks and milk. It was also possible to follow aging processes of milk and orange juice when stored at room temperature.

Chemicals:

The samples in the experiment consisted of 6 different brands of orange juices.

Equipment:

The experiments were carried out in a standard three electrode configuration shown in fig 3, containing a double working electrode 1, an auxiliary electrode 2 consisting of a 20 * 50 mm² plate of stainless steel, and a Ag/AgCl (KCl 3M) as reference electrode 3. The double working electrode consisted of one wire of platinum and the other of gold, both with a length of 5 mm and a diameter of 1 mm. The electrode configuration was placed in a 150 ml measurement cell 4, also containing a magnetic stirrer 5 and the cell with content was kept at room temperature. Current transient responses were measured by a potentiostat 6 connected to a PC 7 via an A/D - D/A converter. The PC was used for onset of pulses and measurement of current transient responses and to store data. Via two relays 8, the PC was also used to shift type of working electrode (gold or platinum).

All voltage referred to in the following are versus the Ag/AgCl electrode.

In general for LAPV, a measurement sequence starts by applying a potential during 470 msec., then the voltage is set again to 0 volt during the same time, whereafter the cycle starts all over. By each cycle, the applied potential is decreased by a given value. Measurement values after onset of pulse at 100 msec and 430 msec., respectively, are collected, as well as the measurement value obtained 100 msec. after offset of the pulse, making altogether 3 data points for each cycle. A typical recording is shown in Figure 4, also showing the position of the measuring points. The pulse time, L1, and time between pulses, L2, are also indicated in the figure.

For the SAPV, the potential is scanned from a start value to a final value, and small voltage pulses are superimposed. Each cycle starts by decreasing the potential with a step value during 180 msec., followed by increasing the potential with a superimposed value during 180 msec. Measuring points are collected 100 msec after onset of the step potential and 100 msec after onset of the superimposed potential. The difference between these two measurement points is also taken as a data point, making altogether 3 data points collected for each cycle. A typical recording is shown in Figure 5, also showing the position of the measuring points. The pulse time, L1, and time between pulses, L2, are also shown in the figure.

Data analysis:

Principal component analysis on the data obtained was performed with a commercial software.

Results obtained of the prototype:

An experimental series were performed, the samples investigated are shown in Table 1. A PCA plot for the whole series of samples is shown in Figure 6. The samples were normalized by dividing by mean in each column. A clear separation between the various samples can be seen.

In the above experiment the concept of an electronic tongue based on the invention demon-

strates its capabilities in being able to classify various fruit drinks and milk, and also to be able to follow some aging processes. This opens up future possible applications in e.g. the food industry.

A further development of the concept is also to use other metals as working electrodes, such as palladium, rhodium and iridium or in some other way change the electrode properties by e.g. surface modifications, use of alloys, etc.... Furthermore, electrodes and setups may be used where the measuring electrodes or special electrodes influence the tested liquid. The invention is not limited to liquid matter since solid matters can be tasted by wetting and then testing.

In a practical embodiment of the invention a tasting cell can be a part of a simple pump, for instance a rotary vane pump. The electrodes may be arranged in a wall of the pump body. The axial wall or the peripheral wall. The vane is preferably provided with a brush part that serves as some sort of a seal against the wall. The brush will of course not provide a watertight seal, but since this pump is not intended to give pressure this is not important. What is important is however that the electrodes will be continuously swept clean by the brush. Also the pump or tasting cell will be extremely unsensitive to larger particles. Actually the vane may be constituted entirely of a brush like structure. Alternatively the vane may be a rubber blade pretensioned against the wall of the cell.

Alternatively the pump may comprise a screw in a cylinder, in the wall of which the electrodes are arranged.

The fast measuring or sampling according to the invention allows the use of many electrodes with variations between them as has been described above to give a good base for the use of multivariate recognition or analyzing methods. Together with the above tasting cell two further advantageous possibilities exist.

To start with identical electrodes may be arranged in the feed direction of the pump. If the electrodes consume some molecules in the test sample a reaction decline from electrode to electrode can be measured, or if the electrodes instead leads to an increase in a substance

a reaction increase will be detected. This decline or increase may also constitute a part of the recognition pattern.

Secondly the identical electrodes may serve as reserves for each other so that even if one or indeed several become clogged or destroyed the redundant system can continue to measure, but preferably with an indication that all is not well with the cell.

In the case with a screw like brush element centrally in the taste cell, the center of the brush element may constitute auxiliary or reference electrode with the working electrodes on the cylinder wall. The electrodes on the wall may be constituted by circles rendering them rather unsensitive to variations in the measured sample. Also this makes its possible to fabricate a very rugged cell body in a simple way by simply arranging alternating cylindric conductive and insulating rings on top of each other. The electrodes may instead have an axial extension.

Preferably the feeding speed of the pump is kept constant at each test and the in tests that are to be comparable.

If the electrode is not continuous around a rotor measuring deviation may occur when the brush passes and shields the electrode. by synchronizing the rotation with the pulse frequency this effect can be made invisible.

Table 1

Sample number	Sample type	Sample number	Sample type	Sample number	Sample type
1	Ph1	16	M4	31	OC4
2	Ph2	17	M5	32	OA3
3	Ph3	18	M6	33	OA4
4	Ph4	19	OE1	34	OB3
5	Ph5	20	OE2	35	OB4
6	OA1	21	OE3	36	SA1
7	OA2	22	OF1	37	SA2
8	OB1	23	OF2	38	SA3
9	OB2	24	OF3	39	SB1
10	OC1	25	OD1	40	SB2
11	OC2	26	OD2	41	SB3
12	OC3	27	OD3		
13	M1	28	A1		
14	M2	29	A2		
15	M3	30	A3		

Table 1

The experimental series carried out consecutively. The samples are:

Phosphate buffer at pH 7.0: Ph

Orange juice: OA, OB, OC, OD, OE, OF

Milk: M

Apple juice: A

Orange still drink: SA, SB

References

- [1]C. Di Natale, F. Davide, A. D'Amico, A. Legin, A. Rudinitskaya, B.L. Selezenev and Y. Vlasov, "Applications of an electronic tongue to the environmental control", Technical digest of Eurosenors X, Leuven, Belgium (1996) 1345-1348.
- [2]K. Toko, "Taste sensor with global selectivity", Materials Science and Engineering C4 (1996) 69-82.
- [3]A. Legin, A. Rudinitskaya, Y. Vlasov, C. Di Natale, F. Davide, A. D'Amico, "Tasting of beverages using an electronic tongue based on potentiometric sensor array", Technical digest of Eurosenors X, Leuven, Belgium (1996) 427-430.
- [4]Y. Sasaki, Y. Kanai, H. Ushida and T. Katsube, "Higly sensitive taste sensor with a new differential LAPS method", Sensors and Actuators B 24-25 (1995) 819-822.
- [5]S. Yamakawa and A. Yamaguchi, "Optical responses of potential-sensitive dye/PMMA coatings to taste solutions", Sensors and Materials 7, 4 (1995) 271-280.
- [6]Y. Kanai, M. Shimizu, H. Uchida, H. Nakahara, C.G. Zhou, H. Maekawa and T. Katsube, "Integrated taste sensor using surface photovoltage technique", Sensors and Actuators B 20 (1994) 175-179.

C L A I M S

1. Measuring method, **characterized in** a generation of transients by applying electrical pulses to electrodes in contact with the substance to be investigated, the transients are registered, already from the onset for the initial transient or to end of the decline at the pulse end and the transients are then evaluated by multivariate methods.
2. Measuring method, **characterized in** a generation of transients by applying electrical pulses to electrodes in contact with the substance to be investigated, the transients are registered, with at last one measured value after the onset of the pulse and at least one measured value before the peak value and the obtained measured values are then evaluated by multivariate methods.
3. Measuring method, **characterized in** a generation of transients by applying electrical pulses to electrodes in contact with the substance to be investigated, the transients are registered, with at last the peak value after the onset of the pulse and the obtained measured values are then evaluated by multivariate methods.
4. Measuring method, **characterized in** a generation of transients by applying electrical pulses to electrodes in contact with the substance to be investigated, the transients are registered, with at last one measured value after the peak of the initial pulse but before the response has fallen below 90% of the peak value and the obtained measured values are then evaluated by multivariate methods.
5. Measuring method, **characterized in** a generation of transients by applying electrical pulses to electrodes in contact with the substance to be investigated, the transients are registered, with at last one measured value after the peak of the initial pulse but before the response has fallen below 90% or preferably 95% of the peak value, one value before the peak, and the peak value and the obtained measured values are then evaluated by multivariate methods.
6. Method according to claim any of the preceding claims, **characterized in** that for each

pulse is one of the entities: current, voltage, energy, conductivity or effect controlled while one of the others entities is registered, for example in the case of current being measured voltage or conductivity may be controlled, whereas in the case of the effect being controlled either the current or the voltage may be registered.

7. Method according to any of the preceding claims, **characterized in** subsequent electric pulses being varied for instance to their current and/or voltage values, to their shape, or in the relation between pulse and pause between the pulses, or the frequency, alternatively the pulses may be superimposed on a rising or falling current or voltage curve.

8. Method according to preceding claim 7, **characterized in** the variation of at least two parameters one electric and one other, providing a two dimensional response pattern.

9. Method according to any of the preceding claims, **characterized in** the use of a number of different measure electrodes of for instance different materials or coated by different materials, or modified in different ways.

10. Method according to any of the preceding claims, **characterized in** the use of a number of different measure electrodes placed so in relation to each other that the electrodes influence each other or that their measuring influence each others result.

11. Method according to any of the preceding claims, **characterized in** the measuring principle being voltametric, potentiometric or conductometric, and of one, two or three electrode type.

12. Method according to claims any of the preceding claims, **characterized in** a cyclic subsequent switching of a common current or voltage generator and/or a registration device between different measuring electrodes resulting in ample time between the pulses to each electrode to allow the influence of the previous pulse on the liquid to have ceased before next pulse arrives to the same electrode.

13. Method according to any of the previous claims, **characterized in** a variation of the

pulse frequency.

14. Method according to any of the previous claims, **characterized in** a variation of the pulse amplitude.

15. Method according to any of the previous claims, **characterized in** the transients being treated with suitable shape enhancing or developing techniques, as for instance derivation, integration, proportionality, etc. before the evaluation by means of multivariate recognition methods or other similar classification methods.

16. Method according to any of the previous claims, **characterized in** a great variation of the pulse frequency, for instance 10 Hz - 100kHz.

17. Electronic tongue, **characterized in** comprising a pulse generator coupled to electrodes for the contact with the substance that is to be investigated, a registration device for registering the transients obtained at the applying of the pulses and a computer for evaluation of the transients with multivariate pattern recognition methods.

18. Electronic tongue, **characterized in** the computer being coupled also to control the pulses to their size shape or frequency etc. or to interact between the pulse generated and the measured response.

19. Measuring or tasting tongue or cell **characterized in** comprising a pump housing in which a pump element is rotatable to cause a flow of the test specimen through the housing, the rotor being provided with a brush or rubber seal that sweeps clean electrodes arranged in the housing wall.

20. Measuring testing cell or tongue according to claim 19, **characterized in** a constant speed during testing.

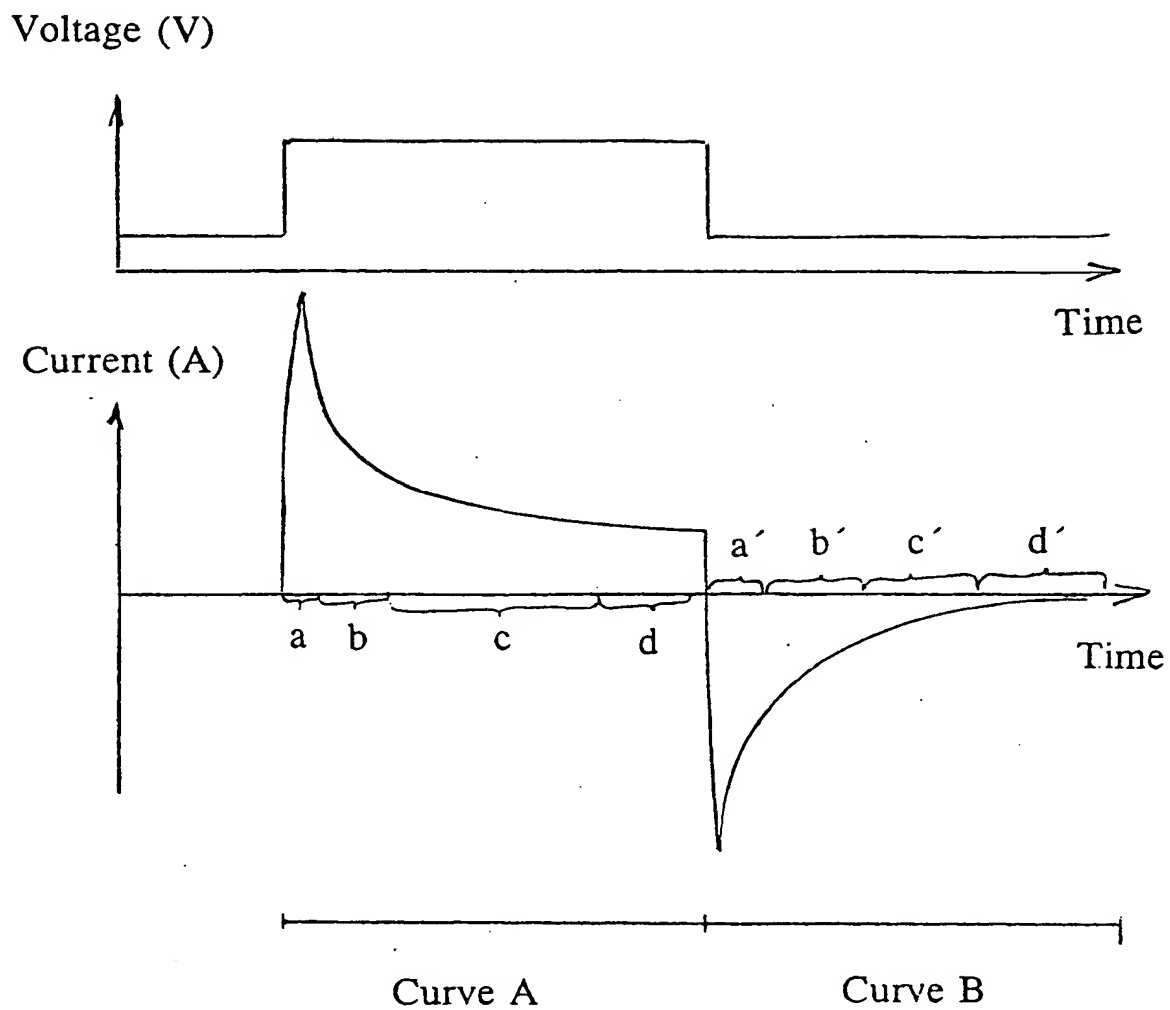


Fig. 1

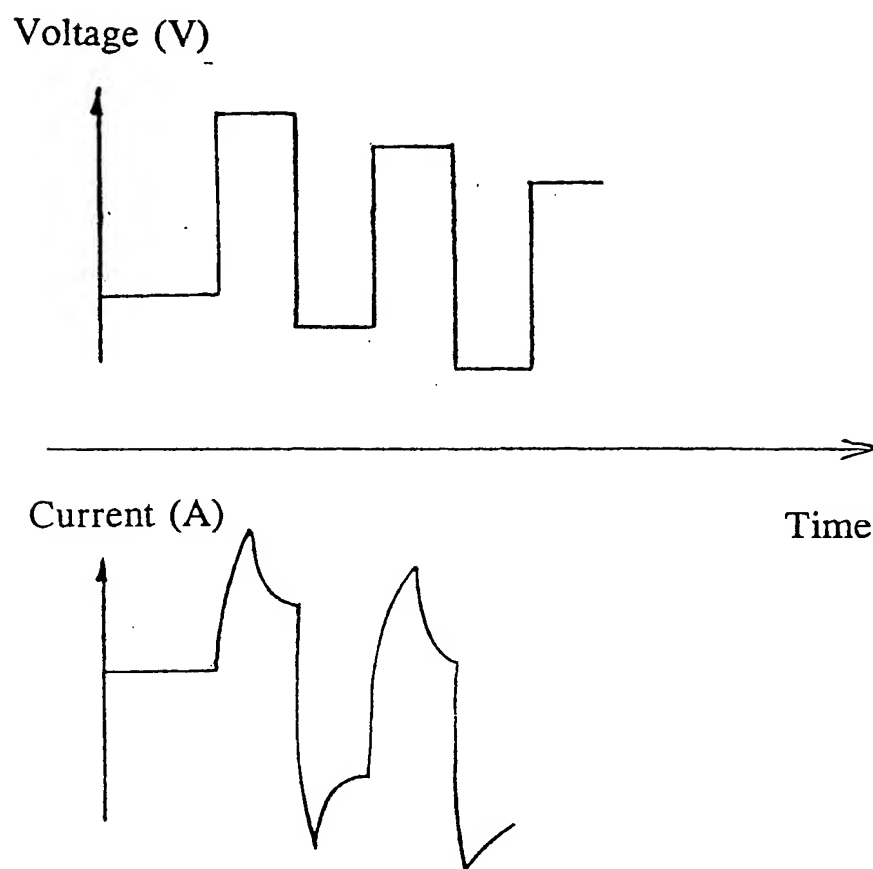


Fig. 2

3/6

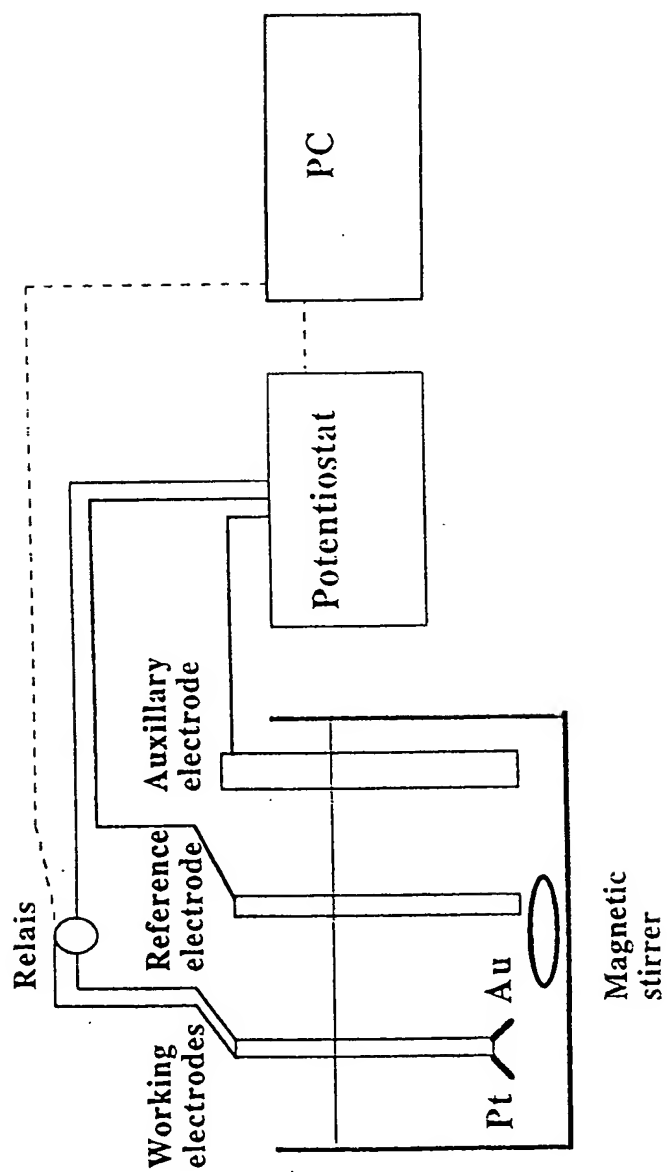


Fig. 3

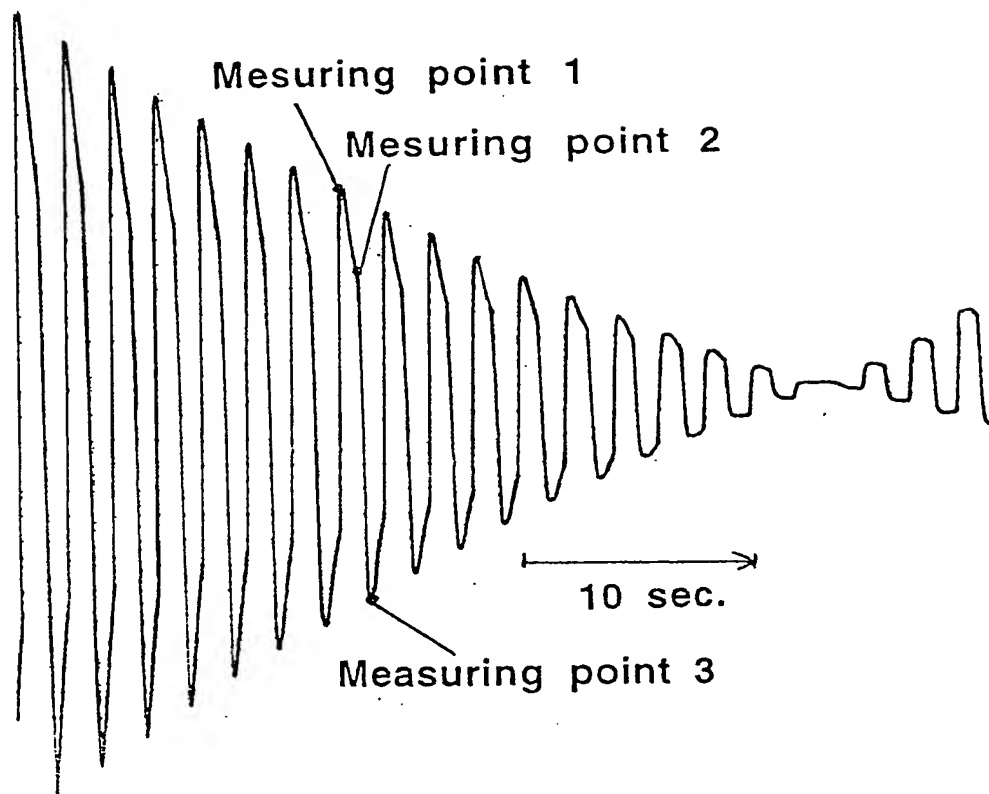


Fig. 4

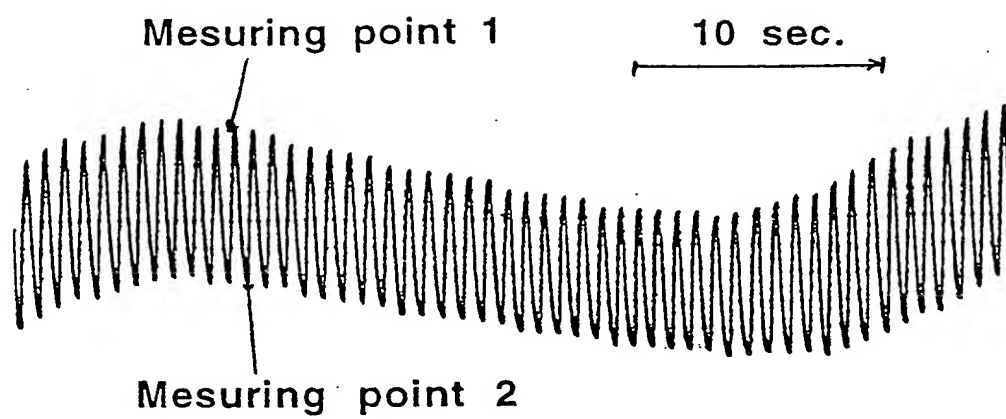


Fig. 5

6/6

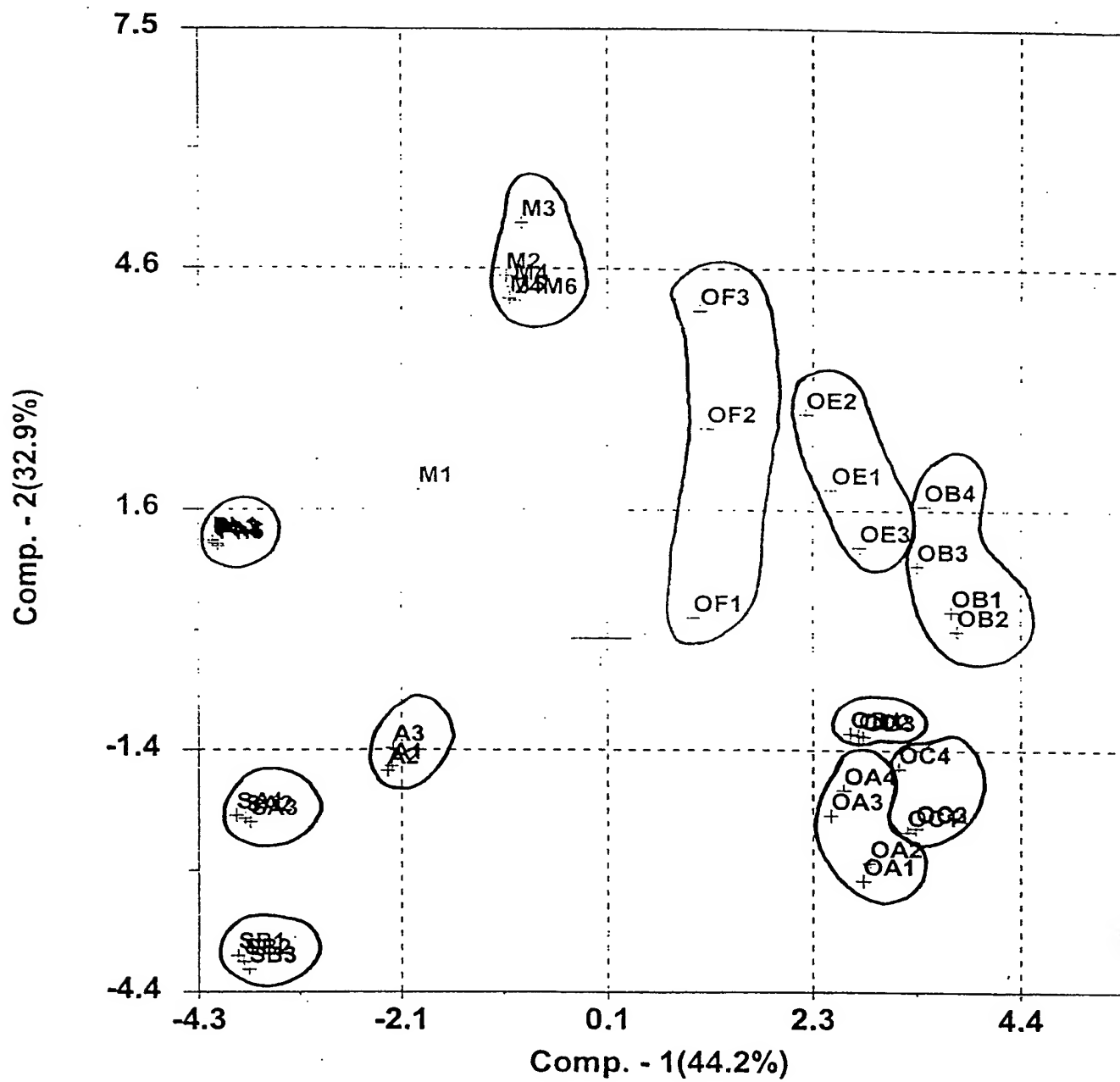


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 98/01583

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G01N 27/416, G01N 27/416, G01N 33/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EPODOC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2127977 A (CESKOSLOVENSKA AKADEMIE VED), 18 April 1984 (18.04.84), page 1, line 81 - line 87, claim 1	1-16
A	--	17-18
X	US 4897162 A (JAN LEWANDOWSKI ET AL), 30 January 1990 (30.01.90), column 4, line 8 - line 9; column 6, line 3 - line 18	1-16
A	--	17-18
X	US 4321322 A (JOSEPH E. AHNELL), 23 March 1982 (23.03.82), column 3, line 24 - line 29; column 6, line 65 - column 7, line 43, claim 1	1-5,9-14
	--	

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

20 January 1999

Date of mailing of the international search report

01-02-1999

Name and mailing address of the ISA/

Swedish Patent Office

Box 5055, S-102 42 STOCKHOLM

Facsimile No. +46 8 666 02 86

Authorized officer

Marianne Bratsberg

Tel. No. +46 8 782 26 00

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 98/01583

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0557642 A2 (KAGOME KABUSHIKI KAISHA), 1 Sept 1993 (01.09.93), column 3, line 3 - line 32 --	7,18
X	Sensors and Actuators B, Volume 44, 1997, Andrey Legin et al, "Tasting of beverages using an electronic tongue" page 291 - page 296	17-18
A	--	1-16
X	Sensors and Actuators B, Volume 44, 1997, C.Di Natale et al, "Multicomponent analysis on polluted waters by means of an electronic tongue", page 423 - page 428, abstract	17-18
A	abstract -- -----	1-16

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE98/01583

Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. Claims 1-17 directed to a measuring method applying electrical pulses to electrodes.
 2. Claims 19-20 directed to a measuring cell comprising a pump house with a rotor being provided with a brush.
 3. Claim 18 directed to a measuring method with computer control of the pulses.
-
1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
 2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
 3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

BEST AVAILABLE COPY

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-18

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT
Information on patent family members

01/12/98

International application No.
PCT/SE 98/01583

Patent document cited in search report			Publication date	Patent family member(s)		Publication date
GB	2127977	A	18/04/84	CS	231026 B	17/09/84
US	4897162	A	30/01/90	NONE		
US	4321322	A	23/03/82	AU	6059280 A	05/01/81
				BE	883881 A	16/10/80
				CA	1158720 A	13/12/83
				EP	0030962 A	01/07/81
				WO	8002849 A	24/12/80
EP	0557642	A2	01/09/93	JP	5240838 A	21/09/93